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Mechanism of Removal of Fluid and Particulate Material from the Respiratory Tract of the Duck

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The mechanism of absorption of fluids, foreign proteins, and particulate matter from the respiratory tract of mammals has been studied. Robertson,[1] in 1941, after reviewing the literature, pointed out that the principle means employed by the body for the immobilization and removal of particulate matter was phagocytosis by large ameboid cells referred to as alveolar phagocytes or "dust cells of von Innes." These cells enter the lymphatics and pass to the lymph nodes. The rate at which carbon-laden macrophages migrate into the lymph channels is slow. Drinker and Field[2] thought that certain kinds of minute particles passed directly into the lymphatics without the intermediate step of phagocytosis.

In 1903, MacCallum[3] was very much interested in the mechanism of absorption of granular materials from the peritoneum. He commented:

> . . . there has been for a long time a desultory discussion as to the manner in which various materials are absorbed from the peritoneum and even in the case of solutions it does not yet seem quite clear whether they are absorbed exclusively by the lymphatics or very largely by the veins. . . . To explain the passage of these granules through the endothelial wall into the lumen of the lacuna, it seems necessary to suppose that the connections of the endothelial cells are so lax that the violent pumping action of the respiratory movement is enough to force material between them when they come to form the only obstruction to its entrance.

It would seem to be the consensus that direct absorption through the mucosa of the larynx, trachea, and bronchi is slight. Little absorption occurs from the pulmonary alveoli, with the exception of water and simple crystalloids.[4] Colin,[5] in 1873, gave 25 liters of water intratracheally to a horse within a period of three hours without serious consequence. Winternitz[6] and Smith observed that isotonic saline in dogs was absorbed very rapidly from the alveoli. Absorption of foreign serum from the respiratory tract does occur in guinea pigs and dogs; however, the degree of absorption is minimal.[7,8] Drinker et al.[8] showed that horse serum was transferred in the dog directly from the alveoli to the blood.

The anatomic structure of the respiratory system in the duck is similar in many ways to that of mammals. However, there are certain fundamental differences that would suggest a possible variation in function. There are no lymph nodes in the duck. The deep lymphatics of each lung are drained by vessels which emerge with the pulmonary vein. The superficial lymphatics of the lung form a wide network on its lower surface. Vessels emerge from this latter network at its outer edge and join the lymphatics following the internal thoracic artery. These lymphatic channels commence as branches draining the abdominal muscles and the diaphragm. They receive the pulmonary lymphatics and branches from the ribs and intercostal muscles and then communicate with the anterior vena cava.[9]

Air sacs, of course, are characteristic anatomic structures in birds.[10] There are nine air sacs in the chicken and duck and seven in the turkey.[10-12] The total volume of these air sacs in the duck is probably four to five times greater than that of both lungs combined. All of the air sacs in the

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duck communicate directly with the larger bronchi, and some are continuous with the sternum, humerus, and vertebrae.

Little attention has been given to the mechanism of the removal of fluid and particulate matter from the respiratory tract of birds. In the present study isotonic saline, fluorescein sodium, saccharated iron oxide, India ink, liquid petrolatum, and Lipodium spores were put into the trachea of white Pekin ducks. Observations were made to determine how these substances were removed from the respiratory tract.

Methods and Materials

White Pekin ducks varying in age from 1 month to 2 years were used. They were kept in small batteries in the laboratory during the time of the acute experiments and in an outside pen for the longer experiments. Food and water were available to them at all times. The intratracheal injections were made with a syringe and an attached small plastic catheter 5 cm. in length. The mouth was opened manually. When the external larynx was opened for inhalation, the catheter was inserted into the trachea for a distance of 2 to 3 cm. The catheter was quickly withdrawn when the injection was completed. Because the birds were held in an upright position with neck elevated for a brief interval after completing the intratracheal injection, regurgitation was reduced to a minimum.

Isotonic saline was given intratracheally to two ducks. The quantity and the time when given are shown in Figure 1. A total of 320 ml. was given to one duck within an interval of two hours. Two hundred milliliters of this fluid was given within a period of 45 minutes. Six ducks were given a single intratracheal injection of 50 ml. of a 0.5% solution of fluorescein sodium in distilled water. Several samples of blood were removed from the leg veins during the first 15 minutes. Other specimens of blood were removed after 4 to 5 hours and after 18 to 24 hours. The blood was citrated and observed for fluorescence with a high-intensity long-wave ultraviolet light.* Usually 4 ml. of blood was put into a test tube with 4 ml. of a 1.0% solution of sodium citrate. Fluorescence was observed after 12 to 24 hours. Control samples of blood were removed before the sodium fluorescence was given.

Twenty-five milliliters of a saccharated iron oxide solution,† containing the equivalent of 100 mg. of elemental iron, or 4 mg. per milliliter, was given intratracheally to one duck. This bird was killed 60 minutes later. A 12.0% concentration of India ink, 0.5 ml., suspended in liquid petrolatum was given intratracheally to 20 ducks. Five of

*A. S. Aloe No. 52140 ultraviolet mineralight, high-intensity long-wave, 3,660 A.

† Feojectin, Smith, Kline & French Laboratories, Philadelphia.

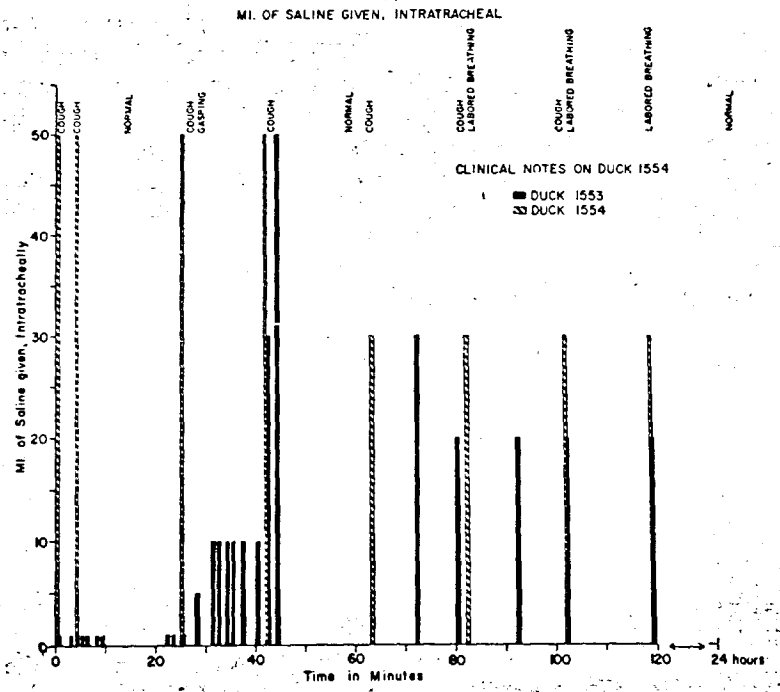

Fig. 1. — Intratracheal injection of saline in the duck. Notice the large amounts given within short intervals of time.

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these were killed 5 to 15 minutes later; five, after 48 hours, and ten, after 65 hours. Ten additional ducks were given 0.5 ml. of the same suspension of India ink in liquid petrolatum daily except for Saturdays and Sundays for 10 days. These birds were killed 24 hours after the last intratracheal injection. Two ducks were given intratracheally 25.0 ml. of a 12.0% aqueous suspension of India ink and were killed five days later.

Liquid petrolatum was given intratracheally to 30 ducks. At each injection 0.5 ml. was given. Ten birds were given 10 daily injections except for Saturdays and Sundays and killed 24 hours after the last. Twenty birds were given 7 to 134 intratracheal injections and killed immediately or up to 18 days later.

All ducks in this experiment were killed by severing of the spinal cord. The ribs were cut on each side. The sternum was reflected onto the neck, permitting good exposure of the thoracic and abdominal viscera and the air sacs. This area then was observed under ultraviolet light for fluorescence in the lungs, air sacs, liver, gallbladder, and intestines. The trachea and lungs subsequently were removed intact. After the trachea was opened and the lungs were sectioned several times, all tissues were carefully examined for fluorescence. When the gallbladder was found to fluoresce, the bile was removed and put into the test tubes for further observations.

Sections were removed routinely from the proximal, middle, and lower third of the trachea and from both lungs. Other sections of tissue were removed for histologic study when gross changes were present. All sections were fixed immediately in a 4.0% solution of formaldehyde. Paraffin sections were prepared and stained routinely with hematoxylin and eosin. Select sections were stained with the periodic acid-Schiff reagent and with the Perl stain for hemosiderin. Osmic acid was used for the demonstration of lipids.

Experimental Data

Sodium Chloride in Trachea of Ducks.—These ducks were markedly dyspneic after receiving 100 to 150 ml. of saline (Fig. 1). Sometimes a small amount of fluid was sprayed from the external trachea. The birds soon returned to normal after the intratracheal injections of saline were discontinued. Forty-eight hours later both lungs were moderately hemorrhagic and slightly edematous. No fluid was present at this time in the air sacs (Fig. 2).

Fluorescein Sodium in Trachea of Ducks.—One adult duck was given intratracheally 50 ml. of fluorescein sodium within a period of two to three minutes. There was a minimum of respiratory difficulty immediately, but 10 minutes later the bird appeared normal. Five additional ducks were given intratracheally 50 ml. of fluorescein sodium. The degree of fluorescence in the blood progressively increased after the fluorescein sodium was given; the maximum intensity was reached 8 to 10 minutes after the injection. The blood removed four to five hours after the intratracheal injection of fluorescein sodium showed less fluorescence than the specimens removed after 10 to 15 minutes. There was no fluorescence in the blood that was removed 18 to 24 hours later. There was no fluid present in the air sacs of the ducks that were killed 18 to 24 hours after fluorescein sodium was injected intratracheally. A small amount of fluorescence, however, was

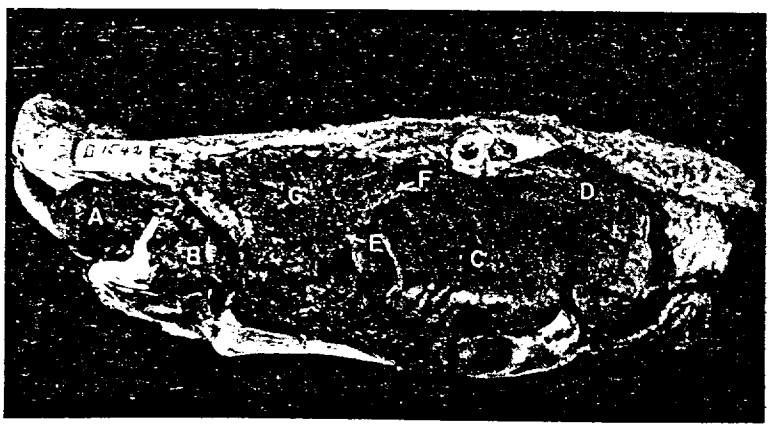

Fig. 2.—Air sacs in the duck after the intratracheal injection of latex. Air sacs: (*A*), cervical; (*B*), clavicular; (*C*), lesser abdominal; (*D*), greater abdominal. (*E*) shows the point of communication between the lung and the lesser abdominal air sac; (*F*) is the area of communication between the lung and the greater abdominal air sac; (*G*) is the lung.

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present along the wall of the air sacs in three of the four ducks killed 18 to 24 hours after the intratracheal injection of the fluorescein sodium.

The gallbladder and portions of the small intestines fluoresced in the four ducks that were killed 18 to 24 hours after the intratracheal injection of the fluorescein sodium. When the bile was removed and put into a test tube there was considerable fluorescence. There was no fluorescence either of the bile or of the contents of the loop of the intestines in four normal ducks.

Saccharated Iron Oxide in Trachea of Ducks.—The respiratory tract and the lungs were markedly congested one hour after the intratracheal injection of this preparation of iron. A small amount of brownish-colored fluid was present in the air sacs. Histologic sections stained with hematoxylin and eosin showed a large amount of brown granular material within the lumen of the parabronchi, the air capillaries, and the air sacs. A small amount of this brown-staining material was present in focal areas on the surface of the bronchial epithelium. The stroma beneath the epithelial cells lining the air sacs and the parabronchi was brownish-yellow as a result of the presence of this preparation of iron.

The brown granular material present in the hematoxylin-and-eosin-stained sections stained blue with the Perl reaction for hemosiderin (Fig. 3). A few small blue-staining areas were present within the layers of epithelial cells that line the trachea. The number of such foci was insignificant. Small clumps of blue-staining material were present within the lumen of some of the small lymphatic-like channels in the stroma between the lobules of lung tissue. Sometimes small collections of blue-staining material were present between the endothelial cells lining the lymphatic and vascular channels (Fig. 4).

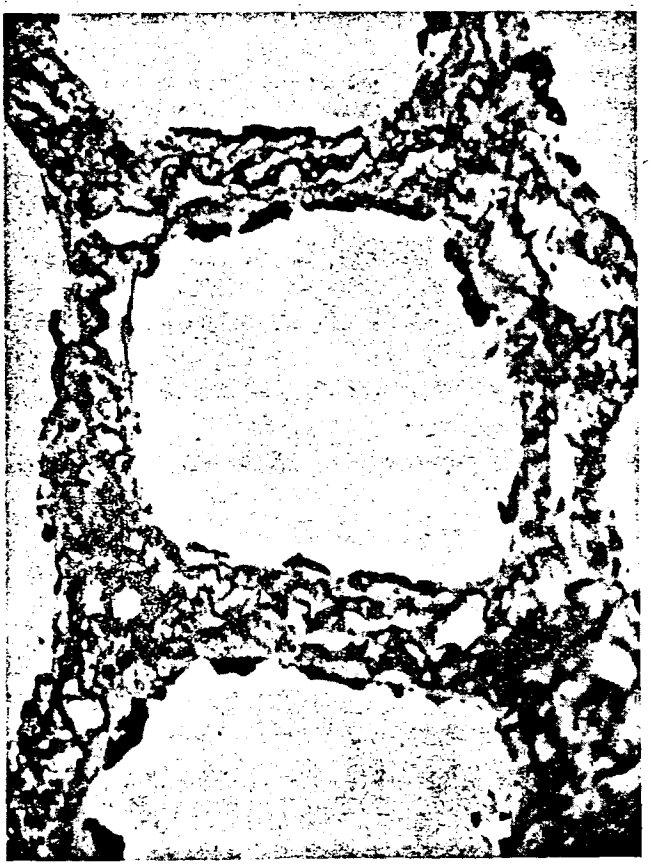

Fig. 3. — Twenty-five milliliters of saccharated iron oxide were put into the trachea an hour before this duck was killed. The iron appears as masses of black staining material on the epithelial surfaces of the parabronchi and in the interstitial tissue. Perl's stain for hemosiderin; × 522.

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Fig. 4.—Either a capillary or lymphatic in the stroma near a bronchus showing an accumulation of iron staining material between and in the cytoplasm of the endothelial cells. The iron is passing from the bronchus into the circulatory system. Perl's stain for hemosiderin; × 950.

India Ink in Trachea of Ducks.—Carbon particles were present macroscopically in the trachea of each of five ducks and in the lungs of three of the five birds given one injection of India ink suspended in liquid petrolatum and killed 5 to 15 minutes later. Two of this group had carbon particles on the wall of the abdominal air sacs. No carbon particles were observed macroscopically in the respiratory tract of the five birds

Fig. 5. — Twenty-five milliliters of India ink were put into the trachea five days before this duck was killed. The particles of ink are present in the stroma of the air capillaries and parabronchi. Hemotoxylin and eosin stain; × 150.

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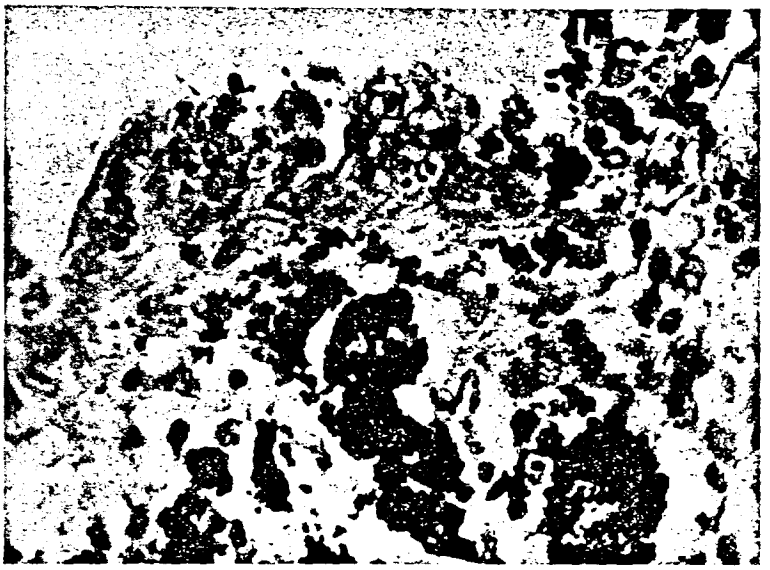

Fig. 6. — Particles of India ink are present between the epithelial cells that line this bronchus. Large masses of carbon particles have collected in the underlying stroma. Hematoxylin and eosin stain; × 260.

given a single injection of the ink in liquid petrolatum and killed 48 hours later. Carbon particles were present macroscopically in the lungs of 4 of the 10 ducks similarly treated and killed 65 hours later.

Two ducks were given intratracheally 25 ml. of the suspension of India ink in distilled water. The birds were killed five days later. Particles of India ink were present in the lumen of the parabronchi and in the

Fig. 7.—Particles of India ink are present in the stroma adjacent to the parabronchi. Hematoxylin and eosin stain; × 1,026.

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Fig. 8.—Fibroblasts proliferate about the carbon particles in the stroma about a small bronchus. Hematoxylin and eosin stain; × 360.

Fig. 9. — Macrophages phagocytize some of the particles of India ink while they are in the stroma. Hematoxylin and eosin stain; × 665.

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Fig. 10.—Carbon particles concentrated in the groups of lymphocytes. Local proliferation of lymphocytes occurs in the lung after the intratracheal injection of foreign material. Hematoxylin and eosin stain; × 120.

lumen and the walls of the air capillaries (Fig. 5). In many areas, where only a few epithelial cells lined the respiratory tract, particles of India ink were present between the cells (Fig. 6). The particles of India ink, after passing through the layer of epithelium and into the adjacent stroma, formed varying-sized masses (Fig. 7). There was a proliferation of the fibroblasts in the stroma about some of the larger collections of particles of India ink (Fig. 8). Granules of India ink were present in the cytoplasm of some of the fibroblasts. Mononuclear cells, apparently histocytes, also were present in the stroma. Many of these cells phagocytized particles of India ink (Fig. 9). Particles of India ink were present within the group of lymphocytes throughout the lung (Fig. 10).

Ten ducks were given an intratracheal injection of the India ink suspended in liquid petrolatum daily for 10 days. They were killed 24 hours after the last injection. No carbon particles were observed macroscopically in the trachea. Carbon particles, however, were present macroscopically in the lungs of 2 and in the abdominal air sacs of 1 of the 10 ducks. Five of these ten birds did have macroscopic lipid material in the lungs and air sacs. Microscopic study of the respiratory tract of these 10 ducks showed the same distribution of the carbon particles as described above. In some of the larger collections of lymphocytes there was considerable carbon pigment. Extensive areas of acute and chronic inflammation were present in the lower portions of the lungs and sometimes also within the air sacs. A few polymorphonuclear leukocytes and lymphocytes infiltrated the mucosa of the trachea. Few granules of India ink were present in the wall of the trachea. Areas of inflammation occurred in the respiratory tract of ducks given intratracheal injections only of liquid petrolatum similar to that present in the birds given India ink suspended in liquid petrolatum.

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Liquid Petrolatum in Trachea of Ducks.—An oily material was present macroscopically in the lungs and in the air sacs of 9 of the 10 ducks given daily injections of liquid petrolatum and killed 24 hours later. There was no macroscopic exudate in the trachea of any of these ducks; however, there was a minimal number of leukocytes and lymphocytes in the wall of the trachea in some of these birds. The lungs, in a majority of the ducks, showed an extensive acute and chronic reaction. A similar reaction was present in the wall of the air sacs.

One of the most interesting lesions observed in the lungs was a local proliferation of lymphocytes. Large groups of these cells were present in the wall of the larger bronchi, and smaller groups of similar cells were present in the stroma between the air capillaries. Sometimes these lymphocytes appeared to develop within the lumen of small vessels, probably in lymph channels (Fig. 11).

Lipid material, as shown by the osmic acid stain, was present in the lumen of the bronchi, parabronchi, air capillaries, and air sacs. Sometimes small globules of lipid-staining material were present within the layer of epithelial cells that line the bronchi. After infiltrating the layer of epithelium that lines the bronchi, these lipid globules accumulated in the stroma in spaces that resembled lymphatics (Fig. 12). Many unidentifiable spaces, some of which may be capillaries, were filled with lipid-staining material. The lumina of some of the small blood vessels were partially filled with lipid material (Fig. 13).

Lipodium Spores in Trachea of Ducks.—Two ducks were given the suspension of Lipodium spores intratracheally and were killed 48 hours later. The lumina of many of the terminal bronchi, the parabronchi,

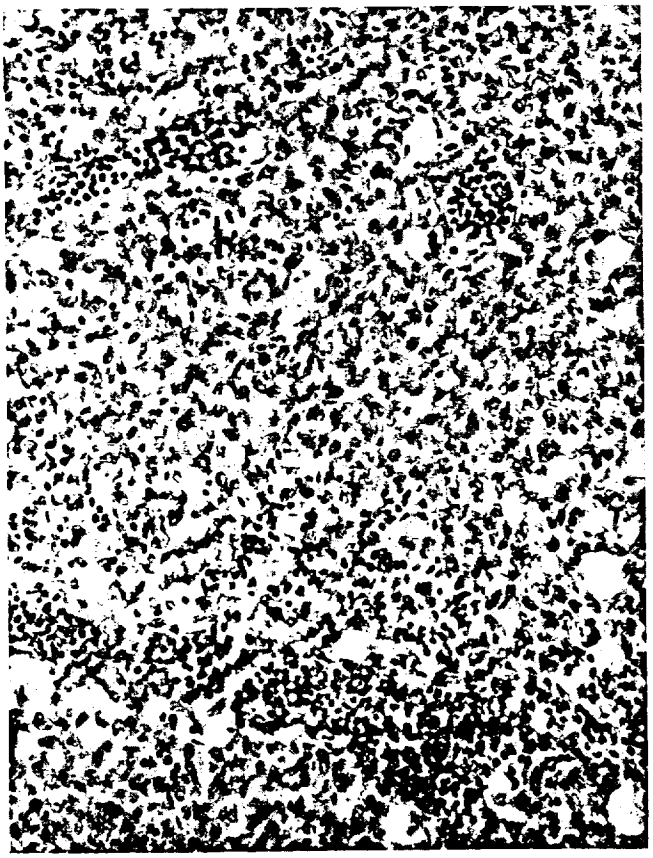

Fig. 11.—Foci of lymphocytes proliferate in the lungs after the intracheal injection of foreign material. Hematoxylin and eosin stain; × 380.

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Fig. 12.—Lipid staining material in the lumen of either lymphatics or blood vessels in the interstitial tissue of the lung after the intratracheal injection of liquid petrolatum. Osmic acid stain; × 190.

and the air capillaries were filled with these spores. Sometimes the spores appeared to have adhered to the surface of the epithelium lining the air passages, while in other areas the spores passed through the layer of epithelium and were present in the adjacent stroma (Fig. 14). Sometimes giant cells surrounded these spores (Fig. 15).

Fig. 13.—The lumen of a small blood vessel in the lung filled with lipid staining material. Liquid petrolatum was put into the trachea 63 hours before this duck was killed. Osmic acid stain; × 280.

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Fig. 14.—A spore in the wall of a bronchus 48 hours after the intratracheal injection of an aqueous suspension of Lipodium spores. Hematoxylin and eosin stain; × 260.

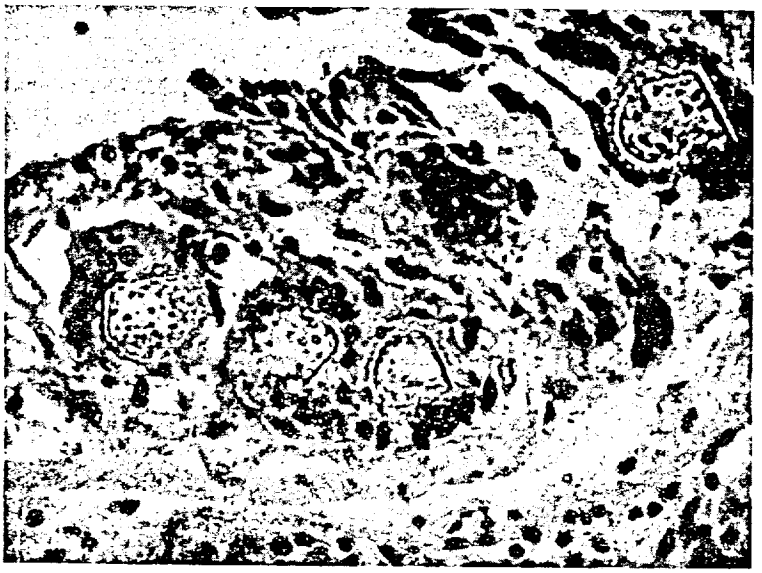

Fig. 15.—Lipodium spores in the stroma beneath the epithelium lining a bronchus. These spores are surrounded by giant cells. Hematoxylin and eosin stain; × 760.

Apparently the spores injured the lining epithelium as they passed from the lumen of the bronchi through the layer of epithelium into the underlying stroma.

Comment

Fluorescein sodium is rapidly transferred from the respiratory tract of the duck into the peripheral circulation. A fluorescent material was present in the blood removed from a leg vein one minute after 50 ml. of 0.5% solution of fluorescein sodium was put into the trachea. It would seem that such a liquid passes rapidly through the layer of epithelium lining the lower portion of the respiratory tract to reach the adjacent stroma. Here it diffuses through the wall of blood vessels and/or lymphatics. The sections removed from the respiratory tract after the intratracheal injection of saccharated iron oxide and stained by the Perl technique for hemosiderin show a large amount of blue-staining material in the stroma and in the wall of some of the smaller vascular channels.

The osmic acid stains made from the tissues of the respiratory tract of ducks given liquid petrolatum intratracheally have many small lipid globules in the layer of epithelium lining the smaller bronchi, the

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parabronchi, and the air sacs. In the stroma immediately adjacent to these epithelial structures are large masses of lipid-staining material. Usually it is impossible to say whether these collections of fat are in a lymphatic or a capillary or are free in the tissue spaces. In a few sections small blood vessels did have lipid-staining material within their lumina. The presence of lipid-staining material within the lumen of these vessels would suggest that globules of the liquid petrolatum had entered either a lymphatic that communicated with a blood vessel or had entered directly a blood vessel.

Sections of the respiratory tract from ducks given intratracheal injections of India ink show very nicely that particulate material passes directly through the layer of epithelium lining the air passages to reach the adjacent stroma. Many of the carbon particles remain in the stroma; however, some are phagocytized. Lipodium spores also pass directly through the layer of epithelium lining the respiratory tract in a manner similar to the particles of India ink and the globules of liquid petrolatum.

This study shows that fluids and particulate material leave the respiratory tract by passing between the epithelial cells that line the walls. After reaching the stroma, some of the particles enter the lumen of lymphatics and/or blood vessels by passing between the endothelial cells that form their walls. Some of the particles, while in the stroma, are phagocytized by macrophages. No doubt, these phagocytic cells with particulate material subsequently enter the pulmonary lymphatics and ultimately reach the lumen of blood vessels.

Particulate material in mammals, as is well known, is phagocytized usually within the pulmonary alveolae. These phagocytic cells then enter the pulmonary lymphatics and are filtered out by the regional lymph nodes. In the duck, phagocytosis has not been observed to occur within the respiratory tract. Small particles are phagocytized by macrophages and fibroblasts within the stroma after they have passed the layer of epithelium that lines the air passages. Giant cells surround the larger particles, such as Lipodium spores, in an attempt to phagocytize them. It would seem from this study that much of the particulate material in the respiratory tract of the duck enters the lymphatics and the vascular system directly without first being phagocytized. Some of the foreign particles are retained within the collections of lymphoid cells that develop in the lungs and in the wall of the bronchi.

The air sacs in the duck appear to be the principal area where particulate material is removed from the respiratory tract. These spaces are lined by a single layer of cuboidal or low columnar epithelium. Particulate material, of course, passes such an epithelial barrier more readily than it passes through the layer of stratified epithelium that lines the trachea.

The mechanism of the removal of fluids and particulate material from the respiratory tract of the duck is most interesting when one compares it with the general concept of the local changes that occur in tissues in inflammation. The latter mechanism has been summarized recently by Gozsy and Kato [13] as follows:

> This response is manifested by a suddenly acquired absorptive capacity of the capillary endothelial cells and the whole inner surface of the capillary tube, providing the endothelial cells with a storing and phagocytizing activity. This phenomenon is followed by a progressively increasing permeability of the cement substance, permitting the active transport of damaging particulate matter, previously absorbed on the vascular endothelium, into the perivascular space.

In the removal of fluid and particulate material from the respiratory tract of the duck, the particles pass through the layer of epithelium into the loose stroma where there are lymphatics and capillaries. The particles then pass from the stroma between the endothelial cells into the vascular and/or lymph channels. In this process some of the particles appear to be phagocytized by the endothelial cells that line the channels. Although we have no experimental data to support the suggestion that these phagocytized particles ultimately are released into

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the circulating lymph or blood, it would seem most likely that such does occur. The removal of particulate material from the respiratory tract of the duck is essentially the reverse to that which occurs in inflammation. In the latter, colloidal dyes, antibodies, and India ink pass from the lumen of the capillaries into the adjacent stroma, while particles pass from the stroma into the capillaries during removal from the respiratory tract. The local factors that make possible this transfer of particles from the respiratory tract to the circulatory system need additional study.

Summary

In the duck, saccharated iron oxide and fluorescein sodium, when put into the respiratory tract through the trachea, pass directly through the layer of epithelium lining the respiratory tract into the stroma and through the wall of the blood vessels and/or lymphatics. Particles of India ink, globules of petrolatum, and Lipodium spores, when put into the respiratory tract of ducks, migrate through the layer of epithelium and either enter the blood vessels and/or lymphatics directly or are phagocytized within the stroma by fibroblasts and histocytes. The transfer of fluids and particulate materials from the respiratory tract of the duck to the vascular system occurs primarily in the air sacs. The variation in the mechanism of removal of particulate material in the duck and in mammals no doubt is necessitated by the differences in the respiratory and lymphatic systems. There are no lymph nodes in the duck as there are in mammals.

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REFERENCES

1. Robertson, O. H.: Phagocytosis of Foreign Material in the Lung, Physiol. Rev. 21:112-139, 1941.

2. Drinker, C. K., and Field, M. E.: Lymphatics, Lymph and Tissue Fluid, Baltimore, The Williams & Wilkins Company, 1933.

3. MacCallum, W. G.: On the Mechanism of Absorption of Granular Materials from the Peritoneum, Bull. Johns Hopkins Hosp. 14:105, 1903.

4. Drinker, C. K., and Yoffey, J. M.: Lymphatics, Lymph, and Lymphoid Tissue: Their Physiological and Clinical Significance, Cambridge, Mass., Harvard University Press, 1941.

5. Colin, G.: Traite de physiologie comparée des animau, Ed. 2, Paris, J. B. Baillière et fils, 1873.

6. Winternitz, M. C.: Collected Studies on the Pathology of War Gas Poisoning, New Haven, Conn., Yale University Press, 1920.

7. Jones, F. S.: The Effects of the Intratracheal Administration of Foreign Serum, J. Exper. Med. 40:63-71, 1924.

8. Drinker, C. K.; Warren, M. F., and MacLanahan, M.: The Absorption of Protein Solutions from the Pulmonary Alveoli, J. Exper. Med. 66: 449-458, 1937.

9. Danfield, J. W.: The Lymphatic System of the Domestic Fowl, Vet. J. 101:179, 1945.

10. Kaupp, B. F.: The Anatomy of the Domestic Fowl, Philadelphia, W. B. Saunders Company, 1918.

11. Rigdon, R. H.: Respiratory System in the Normal White Pekin Duck, Poultry Sc., to be published.

12. Rigdon, R. H.; Ferguson, T. M.; Feldman, G. L., and Couch, J. R.: Air Sacs in the Turkey, Poultry Sc. 37:53-60, 1958.

13. Gozsy, B., and Kato, L.: Studies on Phagocytic Stimulation, Montreal, Institute of Microbiology and Hygiene of the University of Montreal, 1957.

14. Rigdon, R. H.: Capillary Permeability in Areas of Inflammation: The Mechanism of Inflammation, Montreal, Acta. Inc., 1953, pp. 125-133.

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